ELECTRICAL RESISTANCE AND CRITICAL RANGES OF PURE IRON

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The exact location and description of the critical ranges A2 and A3 of pure iron, determined by heating and cooling curves, has recently been published by the Bureau of Standards.[1] Dr. Benedicks, of Stockholm, has since carried out dilatation measurements[2] which show that A2 is accompanied by an expansion change hitherto undetected. Messrs. Honda and Ogura,[3] following a number of other experimenters,[4] have plotted the magnetic and resistance-temperature curves for pure iron over the range 0° to 1000° C. Although their observations appear to give the general trend of the resistance-temperature curve of pure iron, they do not give an exact representation of the resistance changes taking place at A2 and A3, mainly for lack of sensitiveness.

In view of the importance of the subject and as providing a part of an adequate experimental basis for the elucidation of the question of the allotropy of iron it was thought worth while to make as exact a determination of the resistance-temperature relation of pure iron as the experimental means at our command permitted, paying particular attention to the form of the curve over the A2 and A3 critical ranges.

The experiments here described were begun in the summer of 1912, and several preliminary methods of experimentation were tried out before satisfactory sensitiveness, accuracy, speed in

[1] G. K. Burgess and J. J. Crowe: Critical Ranges A2 and A3 of Pure Iron, Scientific Paper No. 213, 1914; also Bull. Am. Inst. Mining Engineers, No. 82, Oct. 1913, p. 2537, and discussion, ibid, Dec. 1913.

[2] Carl Benedicks: Experiments on allotropy of iron; Behavior of ferro-magnetic mixtures; Dilatation of pure iron; J. Iron and Steel Institute, May, 1914.

[3] K. Honda und Y. Ogura: Über die Beziehung zwischen den Änderungen der Magnetisierung und des Elektrischen Widerstandes im Eisen, Stahl und Nickel bei hohen Temperaturen, Science Reports, University Sendai, 3, p. 113, 1914.

[4] See Bureau of Standards Scientific Paper No. 213, above cited.

manipulation, and closeness of observations to each other were obtained. In some of the earlier work the method was tried of bringing the heating bath or furnace to a definite temperature and waiting for equilibrium to be established. It soon became evident that, although great sensitiveness and accuracy could be obtained, nevertheless it would take an infinite time to plot the entire resistance-temperature curve satisfactorily. The method adopted in the final series, and which satisfies all the above requirements, depends on the use of the cooling curve apparatus described in Scientific Paper No. 213 (loc. cit.), together with a very sensitive, quickly manipulated, and accurate Wheatstone bridge, by means of which latter the resistances of an iron wire and one of platinum wound on the same support and inclosed in

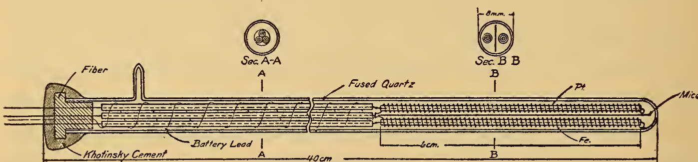

FIG. 1.—*Construction of platinum and iron thermometers*

vacuo in quartz glass may be exactly compared every few seconds by the intermediary of a drum chronograph recording the times at which the resistances are measured; or, in other words, we have used an electrical resistance cooling curve outfit of the highest attainable accuracy and sensitiveness. The temperatures are given in terms of the resistance of the platinum wire, which serves as a thermometer integrating the temperature of the iron wire exactly.

The construction of the combined platinum and iron thermometers is shown in Fig. 1. The platinum and iron wires of 0.2 mm and 0.24 mm diameter, respectively, are wound on thin-walled, unglazed, hard porcelain insulators 6 cm in length and separated by a strip of mica. The thermometers are of the compensated three-lead type, with one common lead and a common battery lead, all four leads being of platinum and provided with porcelain insulators. After winding the coils and before sealing off, the

quartz containing tube was evacuated and, with the coils, heated to a bright red, thus partly annealing the wires and expelling gases. After sealing, the thermometers were again annealed to about 1000° C in the electric furnace. Several platinum and iron thermometers were made in this way, the values of the resistances at 0° C usually being about 1.5 ohms for the platinum and 1 ohm for the iron. The length of the thermometer was about 0.1 that of the specially wound platinum resistance furnace used in taking the resistance observations. The iron was from samples of the purest described in Scientific Paper No. 213 (99.98 per cent iron). The design of the furnace and heating circuits were such that the rate of heating could be exactly controlled and the temperature of the iron was constant over its length at any instant. The Wheatstone bridge with which the best series were taken is one designed by E. F. Mueller, of this Bureau, it being a modification of the one described in Bureau of Standards Reprint 124, in which are also described the methods of use of the resistance pyrometer. The precision of the resistance measurements was better than 0.00001 ohm and of the time 0.1 sec., or equivalent to 0.005° C in temperature differences and to 1 in 1 000 000 of the iron resistance at 800° C. This is some 1000 times the precision of Honda and Ogura.

In all, six iron thermometers were used from three samples, and all gave the same characteristics for pure iron. In Fig. 2 are shown the observations of the second heating and cooling curves taken with thermometer F–6, which are typical of the behavior of iron, and in Fig. 3 the temperature coefficient of electrical resistance of pure iron, or more exactly the ratio of change of resistance of iron to that of platinum with temperature. In Tables 1, 2, and 3 are given the actual observations from which these curves are drawn, except that the lower region of the curve of Fig. 3 is plotted from numerous observations on several iron samples.

In Fig. 2 the observations on heating are represented by circles and on cooling by crosses. The shift of the heating curve with respect to the cooling curve appears to be real, as shown, since the iron returns exactly to the same resistance at 0° C after heating. This noncoincidence of heating and cooling curves is probably

caused by the different rates of heating and cooling, the former being about 0.10 deg./sec. and the latter 0.06 deg./sec. at 900° C.

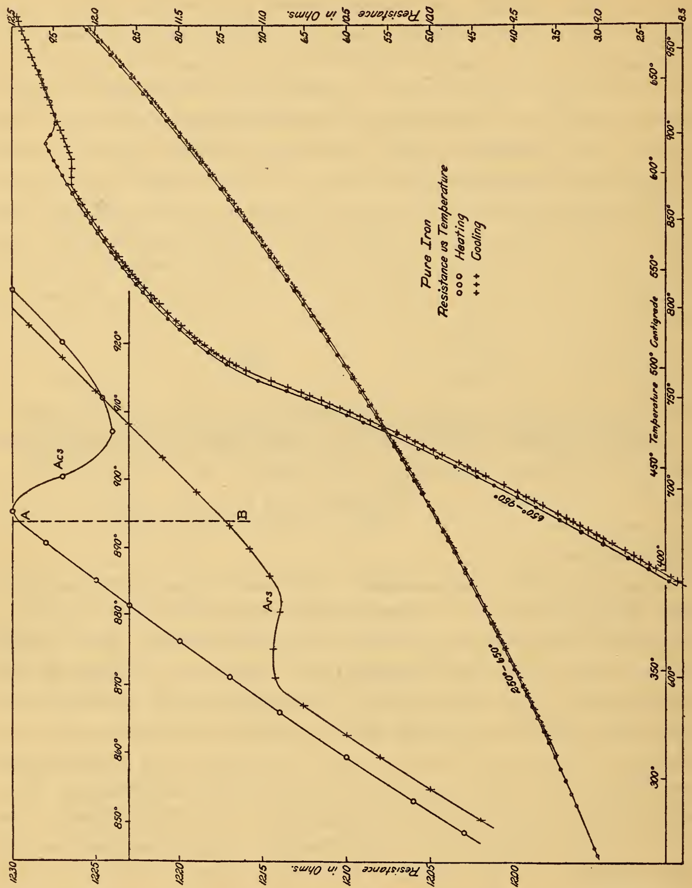

FIG. 2.—*Resistance—Temperature curve of pure iron*

It is seen from Figs. 2 and 3 that the resistance of iron increases from 0.° C without any anomalies except possibly a minute one at 730° C due to less than 0.01 per cent of carbon, with a gradually

increasing temperature coefficient to above 650° or until the neighborhood of A2 is reached. As A2 is approached the resistance rises rapidly, and at A2 there is an inflexion in the resistance-temperature curve shown as a cusp at 757° C in the temperature coefficient curve. At Ac3 the resistance of iron falls abruptly by some 0.005 of its value, which is recovered within a 25° interval, and above Ac3 increases gradually again. On cooling, the reverse phenomenon is observed at Ar3, which is accompanied by a slight increase in resistance with falling temperature, preceded by an

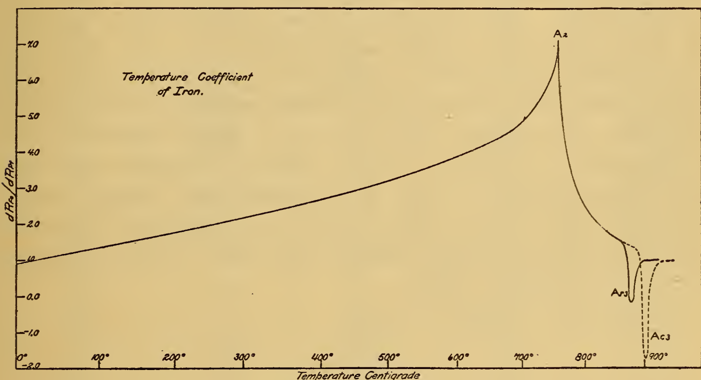

FIG. 3.—*Temperature—Coefficient of pure iron*

interval of relatively slight changes in resistance. These effects are shown best in the open scale plot in Fig. 2 of the A3 region and in Fig. 3.

As closely as can be measured, the transformations Ac3 and Ar3 begin at the same temperature, 894° C (see line AB of Fig. 2); and, as given by the resistance measurements, Ac3 and Ar3 each extend over the considerable temperature interval of 25° C.

These resistance measurements therefore show that A2 is a strictly reversible transformation and that A3 is a transformation taking place at a higher temperature on heating than on cooling. Evidently the two types of transformation are fundamentally different.

The experiments here described are in agreement with the thermal observations previously recorded (see Scientific Paper No. 213), although the position of maximum absorption or evolution of heat does not appear to coincide exactly with the temperatures at which the electrical resistance is changing most rapidly either at A2 or A3. The type of phenomenon is, however, the same as given by either method for A2 and A3, respectively.

Whether or not either or both of these critical ranges, A2 and A3, are to be considered an "allotropic point" will depend on the definition of allotropy, about which there does not yet appear to be agreement. The reversible thermal and electrical behavior at A2 appears to be somewhat similar to that of a pure substance at its melting point, while at A3 there is a progressive change with temperature of the electrical and thermal properties which are not reversible, the reaction taking place at a higher temperature on heating than on cooling. The A3 change is certainly associated with recrystallization, while no crystallographic change has as yet been found at A2, which is also the temperature associated with the abrupt, reversible change of iron from the ferro-magnetic to the para-magnetic states.

WASHINGTON, August 21, 1914.

TABLE 1

Second Heating of F–6

Pt resistance	Time Pt to Fe	Fe resistance	Time Fe to Pt	Pt resistance corresponding to Fe resistance
ohms[5]	secs.	ohms[5]	secs.	ohms
2.76	135.3	2.84	69.8	2.76658
2.77	29.3	2.85	128.5	2.77184
2.78	29.7	2.87	107.3	2.78217
2.79	25.2	2.89	85.2	2.79229
2.80	29.3	2.91	14.0	2.80676
2.81	29.1	2.93	68.0	2.81300
2.82	86.3	2.95	60.2	2.82589
2.83	68.0	2.98	92.0	2.83850
2.85	61.7	3.01	81.0	2.85867
2.87	23.8	3.05	43.7	2.87353
[6] 2.88	....	....	....	....
2.96	29.8	3.26	26.2	2.97596

[5] Resistances are actually read to 0.00001 ohms: thus, for 2.76 read 2.76000, etc.
[6] Increased current in furnace from 3.5 amperes to 5.0 amperes.

TABLE 1—Continued

Second Heating of F-6—Continued

Pt resistance	Time Pt to Fe	Fe resistance	Time Fe to Pt	Pt resistance corresponding to Fe resistance
ohms	secs.	ohms	secs.	ohms
2.99	22.3	3.32	27.6	3.00340
3.02	25.5	3.39	22.6	3.03591
3.05	20.6	3.45	25.3	3.06346
3.08	16.0	3.51	29.0	3.09066
3.11	24.1	3.59	19.7	3.12650
3.14	19.3	3.65	24.1	3.15344
3.17	19.9	3.72	22.5	3.18408
3.20	20.2	3.79	22.9	3.21406
3.23	12.4	3.85	14.0	3.23939
3.25	15.4	3.90	26.0	3.26116
3.28	19.5	3.98	21.0	3.29444
3.31	18.0	4.05	22.1	3.32347
3.34	15.9	4.12	24.2	3.35189
3.37	13.2	4.19	26.0	3.38009
3.40	16.0	4.27	23.2	3.41225
3.43	17.2	4.35	21.4	3.44336
3.46	23.7	4.44	14.8	3.47845
3.49	19.7	4.51	18.5	3.50548
3.52	15.0	4.58	22.0	3.53216
3.55	9.6	4.65	15.3	3.55771
3.57	13.0	4.71	24.8	3.58032
3.60	12.4	4.79	13.6	3.60953
3.62	14.0	4.85	10.0	3.63136
3.64	17.2	4.91	33.8	3.65350
3.68	15.1	5.02	21.6	3.69234
3.71	13.2	5.10	24.2	3.72050
3.74	15.2	5.19	22.0	3.75226
3.77	12.0	5.27	12.4	3.77983
3.79	17.0	5.34	20.2	3.80372
3.82	17.2	5.43	20.0	3.83387
3.85	30.2	5.55	19.7	3.87420
3.89	16.3	5.64	20.7	3.90321
3.92	14.8	5.73	22.3	3.93196
3.95	17.6	5.83	19.1	3.96438
3.98	20.4	5.93	17.0	3.99638
4.01	22.5	6.03	16.6	4.02726
4.04	14.4	6.11	22.2	4.05180
4.07	19.3	6.22	17.9	4.08556
4.10	13.2	6.30	25.2	4.11031
4.13	20.5	6.42	18.1	4.14592
4.16	16.0	6.51	22.6	4.17242
4.19	19.3	6.62	19.8	4.20480
4.22	13.8	6.71	25.1	4.23064
4.25	15.6	6.82	23.7	4.26191
4.28	12.8	6.92	13.6	4.28701
4.30	18.8	7.00	23.3	4.31212
4.33	20.9	7.12	18.6	4.34586

TABLE 1—Continued

Second Heating of F-6—Continued

Pt resistance	Time Pt to Fe	Fe resistance	Time Fe to Pt	Pt resistance corresponding to Fe resistance
ohms	secs.	ohms	secs.	ohms
4.36	17.3	7.22	23.0	4.37287
4.39	12.7	7.32	15.0	4.39673
4.41	17.8	7.41	21.5	4.42359
4.44	13.3	7.51	27.8	4.44970
4.47	18.2	7.64	22.8	4.48331
4.50	16.2	7.75	25.3	4.51172
4.53	19.8	7.88	21.8	4.54428
4.56	20.4	8.00	22.5	4.57426
4.59	30.9	8.15	25.0	4.61219
4.63	36.0	8.33	21.5	4.65510
4.67	12.4	8.43	31.4	4.67859
4.70	20.8	8.58	23.8	4.71400
4.73	17.3	8.70	27.0	4.74171
4.76	14.0	8.82	31.8	4.76916
4.79	19.2	8.97	26.4	4.80291
4.82	17.8	9.10	28.4	4.83156
4.85	15.3	9.23	31.5	4.85980
4.88	15.3	9.37	17.8	4.88924
4.90	20.7	9.48	21.3	4.91479
4.93	19.2	9.62	13.4	4.94178
4.95	19.3	9.72	28.8	4.96204
4.98	12.3	9.85	20.8	4.98742
5.00	15.0	9.96	18.4	5.00898
5.02	16.0	10.07	33.0	5.02980
5.05	17.3	10.20	32.4	5.06043
5.08	19.1	10.40	15.0	5.09120
5.10	14.2	10.50	19.6	5.10846
5.12	15.2	10.62	19.8	5.12863
5.14	13.6	10.74	19.8	5.14814
5.16	11.6	10.86	23.2	5.16666
5.18	19.5	11.03	17.4	5.19055
5.20	50.2	11.22	36.0	5.22913
5.25	14.9	11.33	22.2	5.25803
5.27	21.9	11.41	34.3	5.28169
5.30	23.5	11.50	30.5	5.31306
5.33	18.8	11.57	19.8	5.33974
5.35	18.6	11.62	19.3	5.35982
5.37	20.6	11.67	18.0	5.38067
5.39	24.8	11.72	14.6	5.40259
5.41	21.6	11.76	16.7	5.42128
5.43	22.1	11.80	17.5	5.44116
5.45	22.7	11.84	17.6	5.46126
5.47	25.3	11.88	15.0	5.48256
5.49	18.0	11.91	23.2	5.49874
5.51	22.9	11.95	18.2	5.52114
5.53	29.6	11.99	34.1	5.54394
5.56	16.6	12.03	25.2	5.56794
5.58	15.1	12.06	28.1	5.58683

TABLE 1—Continued

Second Heating of F-6—Continued

Pt resistance	Time Pt to Fe	Fe resistance	Time Fe to Pt	Pt resistance corresponding to Fe resistance
ohms	secs.	ohms	secs.	ohms
5.60	27.1	12.10	38.9	5.61232
5.63	19.6	12.14	23.2	5.63915
5.65	22.3	12.17	21.8	5.66011
5.67	25.3	12.20	17.5	5.68182
5.69	29.6	12.23	15.6	5.70310
5.71	18.5	12.25	26.5	5.71822
5.73	25.5	12.28	21.6	5.74083
5.75	22.0	12.30	23.1	5.75974
5.77	29.5	12.27	19.3	5.78029
5.79	41.0	12.24	30.2	5.80727
5.82	18.2	12.246	21.6	5.82728
5.836	60.8	12.27	46.4	5.86090
5.88	31.1	12.30	20.2	5.89213
5.90	33.6	12.32	17.6	5.91310
5.92	34.6	12.34	15.7	5.93376
5.94	....	.....	....	....

TABLE 2

Second Cooling of F-6

Pt resistance	Time Pt to Fe	Fe resistance	Time Fe to Pt	Pt resistance corresponding to Fe resistance
ohms	secs.	ohms	secs.	ohms
6.08	32.8	12.49	22.5	6.07408
6.07	40.0	12.47	14.6	6.06372
6.06	43.7	12.46	66.5	6.05208
6.04	52.3	12.44	51.7	6.02994
6.02	58.2	12.42	40.8	6.00825
6.00	61.0	12.40	36.5	5.98749
5.98	63.6	12.38	28.0	5.96611
5.96	67.1	12.36	24.5	5.94535
5.94	24.8	12.35	21.1	5.93460
5.93	27.0	12.34	18.2	5.92403
5.92	28.7	12.33	15.8	5.91355
5.91	30.0	12.32	14.3	5.90322
5.90	31.8	12.31	56.2	5.89278
5.88	38.3	12.29	46.6	5.87100
5.86	35.0	12.27	49.2	5.85167
5.84	35.4	12.25	48.0	5.83152
5.82	36.2	12.23	30.2	5.81183
5.805	52.8	12.21	47.0	5.79180
5.78	37.2	12.19	46.7	5.77112
5.76	36.7	12.17	25.8	5.75119

TABLE 2—Continued

Second Cooling of F-6—Continued

Pt resistance	Time Pt to Fe	Fe resistance	Time Fe to Pt	Pt resistance corresponding to Fe resistance
ohms	secs.	ohms	secs.	ohms
5.745	29.0	12.158	46.7	5.73772
5.726	21.6	12.146	49.0	5.72110
5.71	43.2	12.14	39.9	5.69960
5.69	51.2	12.144	30.2	5.67744
5.67	41.0	12.143	41.4	5.66005
5.65	25.8	12.126	54.5	5.64359
5.63	16.8	12.10	22.7	5.62574
5.62	29.2	12.08	52.5	5.61285
5.60	25.5	12.05	57.1	5.59356
5.58	19.7	12.02	67.0	5.57546
5.56	37.0	11.98	46.7	5.55116
5.54	47.0	11.94	39.0	5.52908
5.52	31.2	11.91	52.0	5.51252
5.50	15.2	11.88	27.0	5.49642
5.49	17.5	11.86	23.9	5.48577
5.48	20.0	11.84	22.4	5.47528
5.47	20.6	11.82	21.3	5.46509
5.46	19.7	11.80	21.6	5.45518
5.45	18.8	11.78	22.2	5.44542
5.44	18.0	11.76	24.3	5.43514
5.43	14.8	11.74	26.2	5.42638
5.42	31.5	11.71	50.3	5.41232
5.40	23.3	11.67	19.7	5.39458
5.39	16.4	11.65	30.4	5.38650
5.38	21.4	11.62	53.0	5.37428
5.36	29.2	11.57	52.8	5.35289
5.34	25.7	11.52	18.2	5.33416
5.33	28.0	11.49	53.5	5.32312
5.31	19.1	11.44	23.1	5.30546
5.30	19.4	11.41	21.3	5.29522
5.29	19.0	11.38	22.6	5.28542
5.28	16.6	11.35	24.9	5.27600
5.27	24.5	11.31	16.6	5.26404
5.26	18.3	11.28	23.0	5.25556
5.25	21.2	11.24	21.7	5.24506
5.24	17.8	11.20	21.6	5.23548
5.23	14.0	11.16	26.5	5.22646
5.22	23.0	11.10	59.3	5.21442
5.20	40.3	10.95	41.6	5.19018
5.18	18.2	10.85	25.3	5.17582
5.17	23.2	10.77	15.1	5.16394
5.16	17.7	10.72	21.8	5.15552
5.15	24.2	10.65	17.0	5.14413
5.14	17.2	10.60	22.7	5.13569
5.13	17.6	10.54	24.8	5.12585
5.12	17.3	10.48	23.2	5.11572
5.11	19.8	10.42	23.2	5.10573

TABLE 2—Continued

Second Cooling of F–6—Continued

Pt resistance	Time Pt to Fe	Fe resistance	Time Fe to Pt	Pt resistance corresponding to Fe resistance
ohms	secs.	ohms	secs.	ohms
5.10	21.0	10.36	19.7	5.09484
5.09	31.8	10.29	50.6	5.08226
5.07	15.6	10.20	24.0	5.06606
5.06	21.3	10.14	19.2	5.05613
5.05	25.8	10.08	15.1	5.04379
5.04	16.2	10.04	23.2	5.03589
5.03	22.8	9.98	17.8	5.02439
5.02	19.8	9.93	57.5	5.01488
5.00	18.0	9.83	22.1	4.99551
4.99	15.2	9.78	21.6	4.98587
4.98	18.0	9.73	22.0	4.97550
4.97	25.0	9.67	52.1	4.96351
4.95	26.2	9.57	51.2	4.94324
4.93	21.2	9.48	17.3	4.92449
4.92	23.2	9.43	16.1	4.91410
4.91	24.9	9.38	20.8	4.90455
4.90	20.8	9.33	45.8	4.89376
4.88	23.1	9.24	15.1	4.87394
4.87	26.4	9.19	11.7	4.86307
4.86	21.7	9.15	16.9	4.85438
4.85	16.5	9.11	21.3	4.84564
4.84	20.3	9.06	18.4	4.83476
4.83	23.5	9.01	13.5	4.82365
4.82	20.0	8.97	18.8	4.81485
4.81	24.0	8.92	51.7	4.80366
4.79	15.2	8.84	23.0	4.78601
4.78	21.7	8.79	16.0	4.77425
4.77	18.7	8.75	19.2	4.76503
4.76	24.5	8.70	14.3	4.75370
4.75	20.3	8.66	54.4	4.74456
4.73	24.0	8.57	13.7	4.72364
4.72	21.2	8.53	16.9	4.71443
4.71	28.3	8.48	47.5	4.70253
4.69	24.3	8.40	13.3	4.68354
4.68	13.5	8.37	24.3	4.67643
4.67	20.0	8.32	17.4	4.66465
4.66	18.8	8.28	18.2	4.65492
4.65	17.7	8.24	20.1	4.64532
4.64	16.6	8.20	21.2	4.63561
4.63	15.6	8.16	22.0	4.62585
4.62	15.3	8.12	22.9	4.61600
4.61	18.0	8.08	23.4	4.60565
4.60	13.8	8.04	24.0	4.59635
4.59	24.0	7.99	52.0	4.58369
4.57	22.8	7.91	14.0	4.56380
4.56	23.6	7.87	13.7	4.55367
4.55	25.3	7.83	13.2	4.54343

TABLE 2—Continued

Second Cooling of F-6—Continued

Pt resistance	Time Pt to Fe	Fe resistance	Time Fe to Pt	Pt resistance corresponding to Fe resistance
ohms	secs.	ohms	secs.	ohms
4.54	25.0	7.79	12.5	4.53334
4.53	25.8	7.75	13.0	4.52335
4.52	16.1	7.72	21.8	4.51575
4.51	16.4	7.68	20.0	4.50550
4.50	18.9	7.64	17.8	4.49485
4.49	21.0	7.60	17.0	4.48447
4.48	23.0	7.56	53.0	4.47394
4.46	27.0	7.48	12.2	4.45312
4.45	18.3	7.45	20.0	4.44524
4.44	20.6	7.41	17.3	4.43456
4.43	23.3	7.37	13.8	4.42372
4.42	16.6	7.34	22.2	4.41572
4.41	28.8	7.29	10.4	4.40266
4.40	20.5	7.26	15.4	4.39429
4.39	24.5	7.22	13.5	4.38355
4.38	18.0	7.19	20.6	4.37534
4.37	21.5	7.15	17.6	4.36450
4.36	14.2	7.12	24.4	4.35632
4.35	18.0	7.08	20.2	4.34529
4.34	22.2	7.04	16.0	4.33419
4.33	16.1	7.01	21.8	4.32576
4.32	20.6	6.97	17.8	4.31464
4.31	25.0	6.93	12.9	4.30430
4.30	19.0	6.90	19.0	4.29500
4.29	24.2	6.86	14.8	4.28379
4.28	18.0	6.83	19.9	4.27525
4.27	23.0	6.79	14.8	4.26379
4.26	17.8	6.76	19.3	4.25520
4.25	24.0	6.72	14.8	4.24382
4.24	18.0	6.69	19.1	4.23518
4.23	25.3	6.65	14.2	4.22360
4.22	19.1	6.62	19.2	4.21502
4.21	25.4	6.58	12.4	4.20328
4.20	21.0	6.55	17.3	4.19452
4.19	25.6	6.51	49.0	4.18314
4.17	29.6	6.44	46.5	4.16223
4.15	21.5	6.38	16.3	4.14431
4.14	17.5	6.35	20.3	4.13537
4.13	14.1	6.32	24.1	4.12631
4.12	21.6	6.28	16.0	4.11426
4.11	19.0	6.25	19.7	4.10509
4.10	26.7	6.21	48.0	4.09286
[7] 4.08	....	....	....	....
4.03	30.3	5.98	44.3	4.02188
4.01	14.8	5.93	24.3	4.00622
4.00	11.8	5.90	26.5	3.99692

[7] Changed paper on chronograph.

TABLE 2—Continued

Second Cooling of F–6—Continued

Pt resistance	Time Pt to Fe	Fe resistance	Time Fe to Pt	Pt resistance corresponding to Fe resistance
ohms	secs.	ohms	secs.	ohms
3.99	34.0	5.85	42.1	3.98106
3.97	18.3	5.80	19.2	3.96512
3.96	29.3	5.76	16.5	3.94720
3.94	28.0	5.70	49.7	3.93279
3.92	24.8	5.64	11.6	3.91319
3.91	25.3	5.61	12.8	3.90338
3.90	12.8	5.59	25.2	3.89664
3.89	24.4	5.55	51.0	3.88354
3.87	37.2	5.48	39.5	3.86003
3.85	23.2	5.43	14.0	3.84376
3.84	13.2	5.41	25.2	3.83581
3.83	24.3	5.37	13.0	3.82348
3.82	13.2	5.35	25.3	3.81658
3.81	27.0	5.31	11.4	3.80619
3.80	16.0	5.29	22.8	3.79588
3.79	28.1	5.25	48.3	3.78264
3.77	17.3	5.20	20.3	3.76540
3.76	19.4	5.17	18.3	3.75485
3.75	21.2	5.14	16.7	3.74440
3.74	23.7	5.11	14.3	3.73376
3.73	25.1	5.08	51.5	3.72345
3.71	28.8	5.02	46.3	3.70234
3.69	34.9	4.96	42.0	3.68107
3.67	26.5	4.91	11.0	3.66293
3.66	30.8	4.88	47.0	3.65209
3.64	19.0	4.83	16.4	3.63463
3.63	25.7	4.80	10.4	3.62398
3.62	17.3	4.78	21.6	3.61555
3.61	20.7	4.75	17.5	3.60458
3.60	25.1	4.72	13.3	3.59346
3.59	29.3	4.69	48.8	3.58250
[8] 3.57	----	----	----	-------
3.52	21.5	4.51	28.2	3.51567
3.51	30.0	4.45	43.5	3.50184
3.49	29.8	4.40	47.8	3.47848
3.46	26.8	4.35	49.0	3.45292
3.44	27.3	4.30	51.2	3.43305
3.42	26.0	4.25	12.2	3.41319
3.41	19.0	4.23	20.8	3.40522
3.40	25.3	4.20	12.6	3.39332
3.39	17.9	4.18	20.0	3.38528
3.38	27.7	4.15	12.2	3.37306
3.37	19.0	4.13	19.5	3.36506
3.36	28.6	4.10	48.0	3.35260
3.34	30.3	4.05	17.8	3.32738
3.32	33.0	4.00	46.0	3.31165

[8] Chronograph stopped for several minutes.

TABLE 2—Continued

Second Cooling of F-6—Continued

Pt resistance	Time Pt to Fe	Fe resistance	Time Fe to Pt	Pt resistance corresponding to Fe resistance
ohms	secs.	ohms	secs.	ohms
3.30	18.8	3.96	20.1	3.29516
3.29	28.8	3.93	47.7	3.28248
3.27	18.2	3.89	14.0	3.26435
3.26	36.0	3.86	11.7	3.25245
3.25	18.2	3.84	20.8	3.24534
3.24	17.0	3.82	23.1	3.23576
3.23	26.8	3.79	12.2	3.22313
3.22	22.0	3.77	17.7	3.21446
3.21	16.2	3.75	23.1	3.20588
3.20	43.2	3.71	36.0	3.18909
3.18	17.9	3.68	19.9	3.17512
3.17	15.0	3.66	26.2	3.16633
3.16	25.8	3.63	11.6	3.15310
3.15	23.6	3.61	16.7	3.14415
3.14	18.9	3.59	21.2	3.13529
3.13	14.0	3.57	23.8	3.12630
3.12	....	....	....	....

TABLE 3

Resistance in Ice and in Steam

	Pt	Fe (F-6)	Remarks
	Ohms	Ohms	
R_0......	1.4524	0.9713	R_0 and R_{100} for both Pt and Fe same before and after second heating.
R_{100}.....	1.9987	1.5880	For method of computing temperatures, see Scientific Paper 124.
F. I....	0.5463 δ=1.50	0.6167	